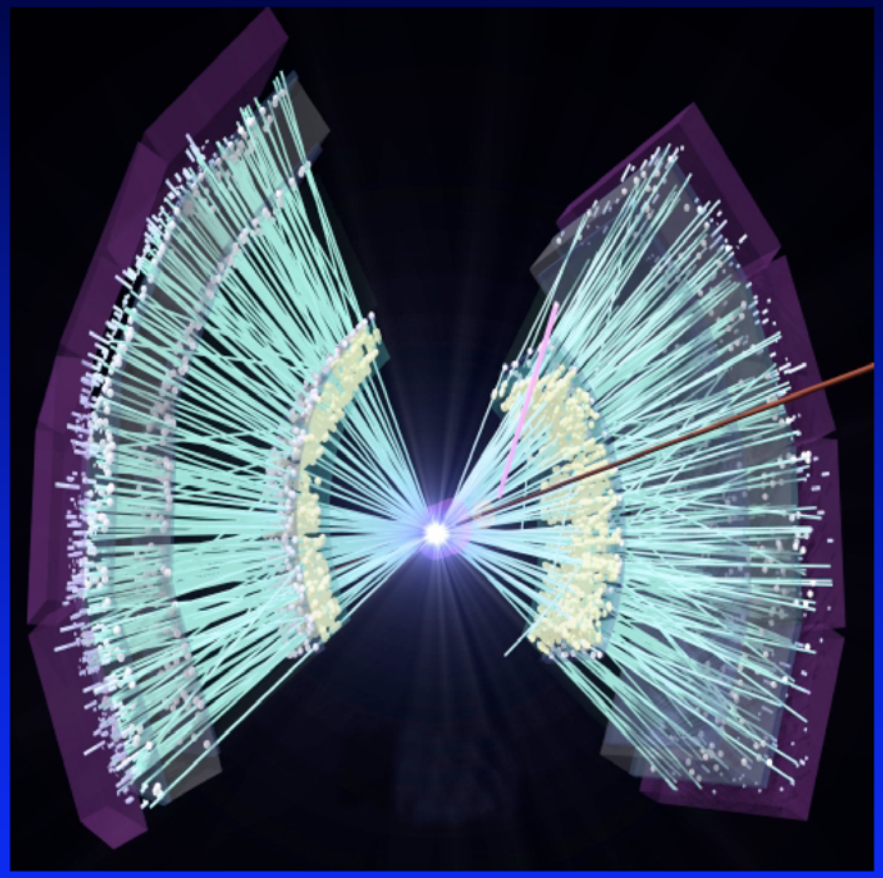
J/ψ Production in Cu+Cu Collisions



Abigail Bickley

University of Colorado

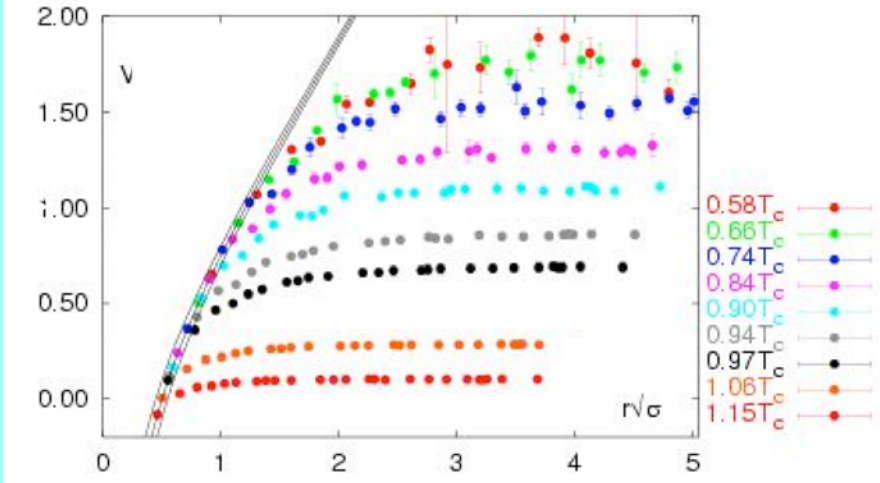
For the PHENIX Collaboration

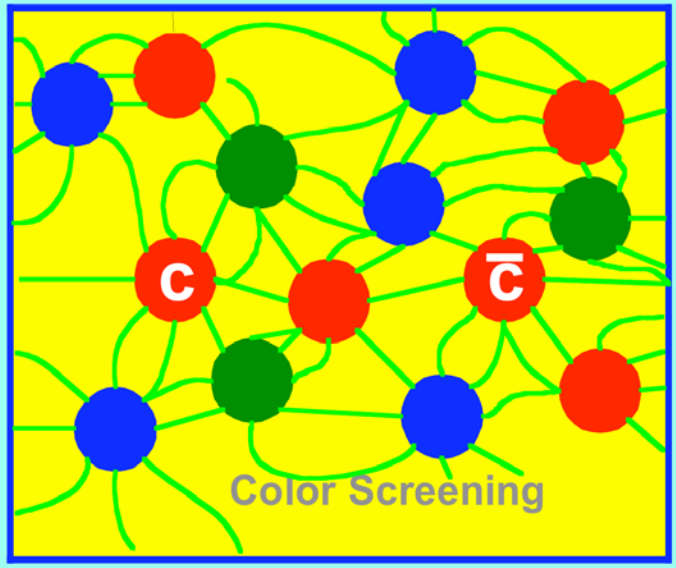
September 19, 2005

Nuclear Matter: Cold vs Hot

- Heavy quarkonia interact with the surrounding medium and provide a useful diagnostic for probing the state of matter present in heavy ion collisions.

- Competing effects predicted to govern J/ψ production in the collision medium
  - J/ψ color screening: Suppression of J/ψ yield with increasing collision centrality





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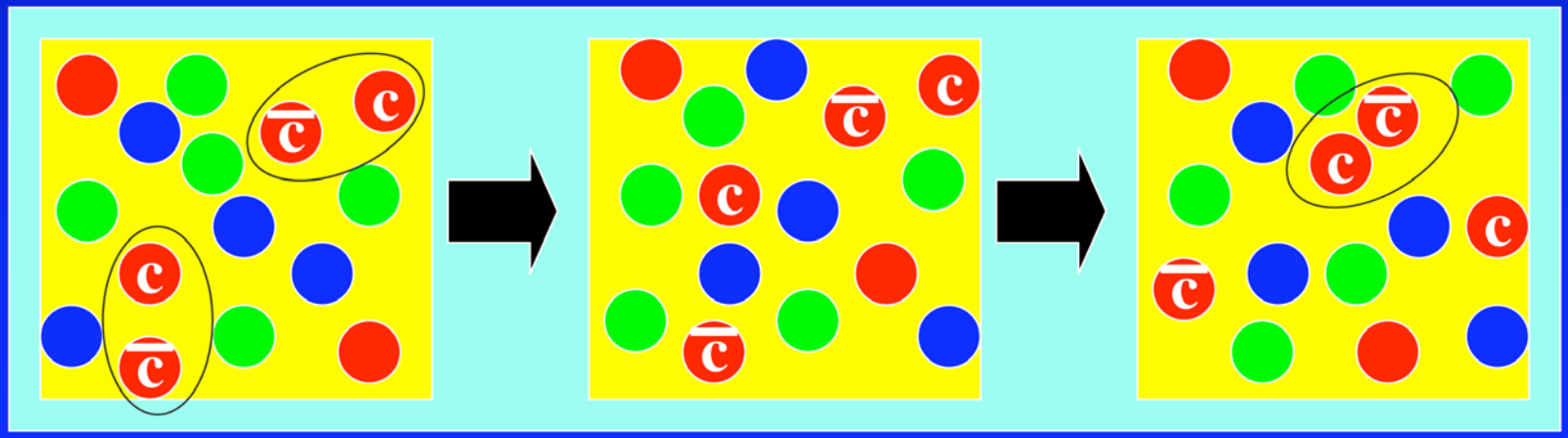

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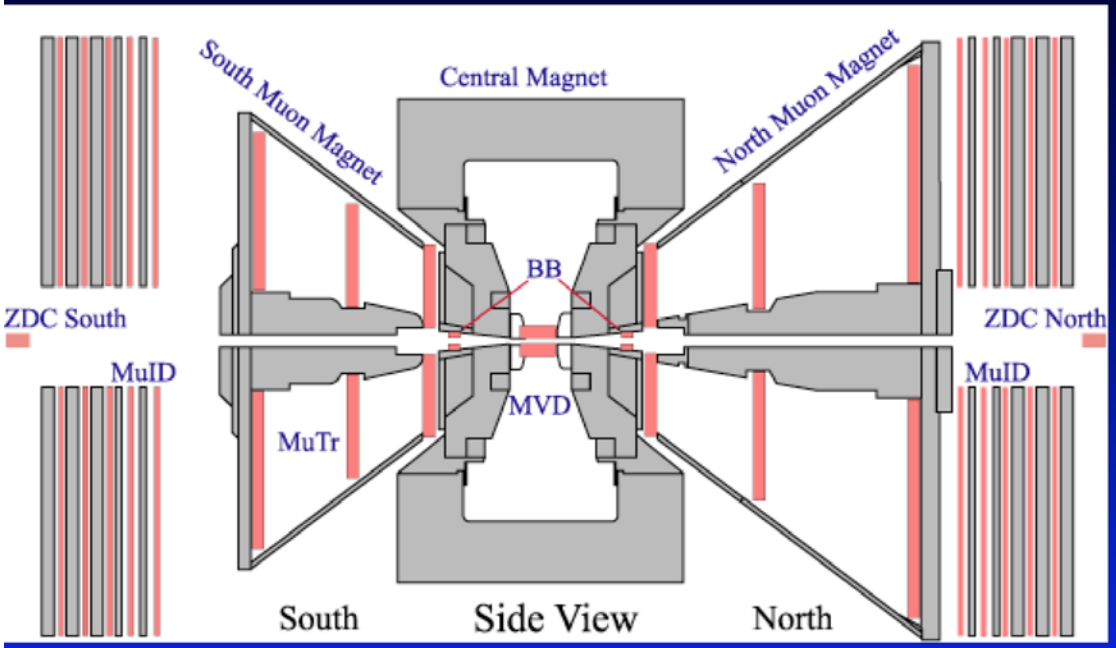
  - J/ψ recombination: Regeneration of J/ψ pairs from independently produced c and cbars
  - Shadowing, Heavy quark energy loss, Normal nuclear absorption, etc
- To understand and interpret the results obtained at the highest RHIC energy densities it is necessary to compare the results with those obtained in smaller, cooler systems.

PHENIX Detector



$J/\psi \rightarrow \mu^+ \mu^-$

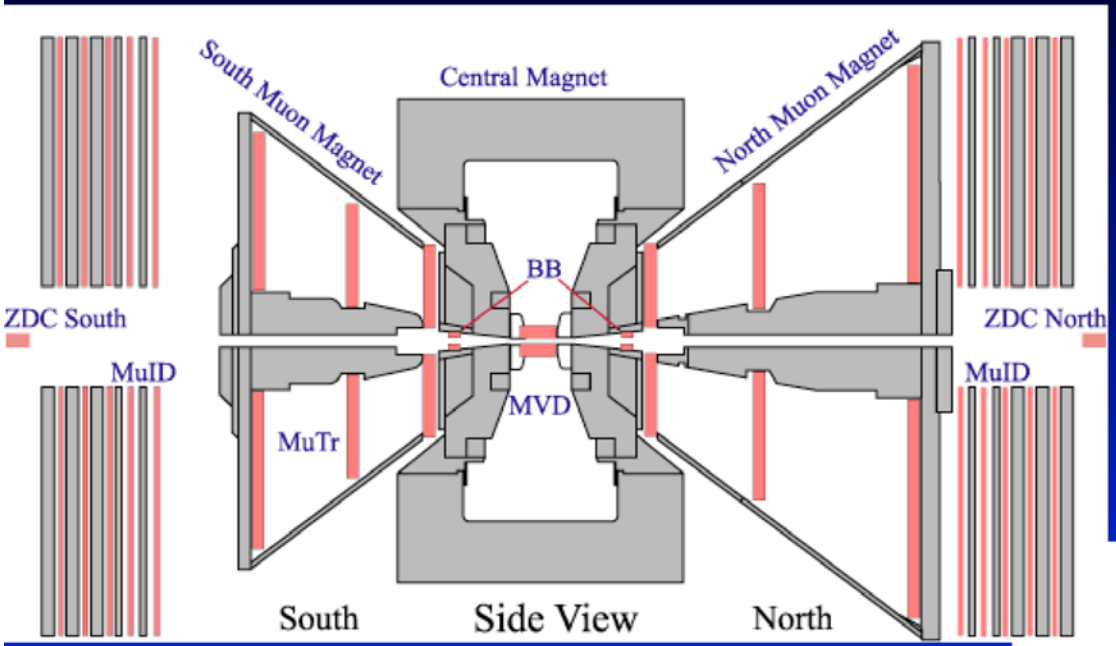
Reconstruct dimuons at forward rapidities

Coverage: $p > 2\text{GeV/c}$

$1.2 < |y| < 2.2$

$\Delta\phi = 2\pi$

PHENIX Detector



$J/\psi \rightarrow \mu^+ \mu^-$

Reconstruct dimuons at forward rapidities

Coverage: $p > 2$GeV/c

$1.2 < |y| < 2.2$

$\Delta\phi = 2\pi$

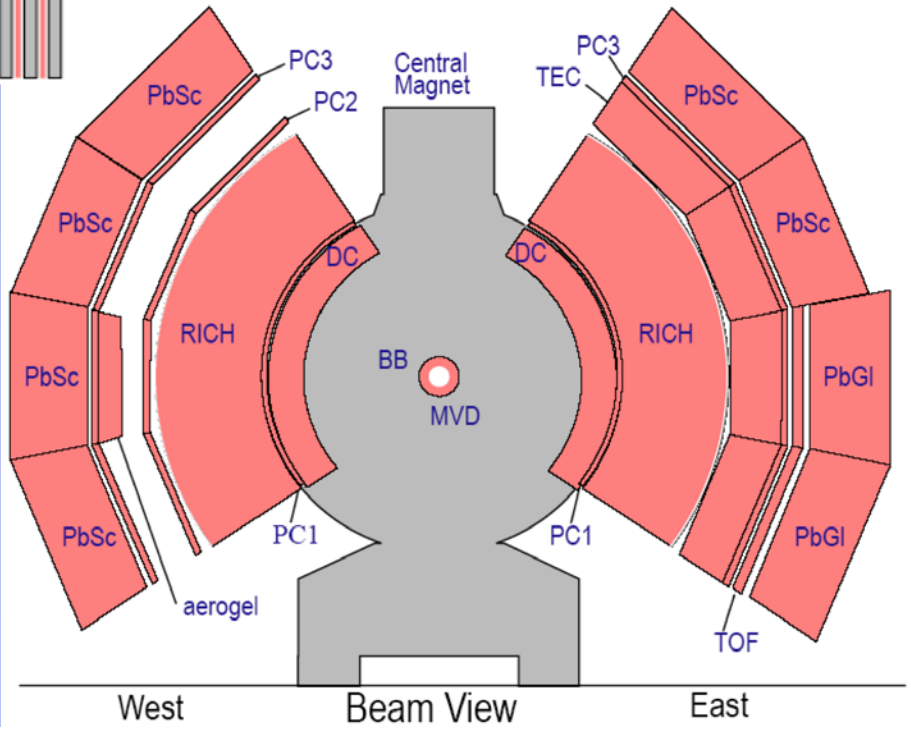
$J/\psi \rightarrow e^+ e^-$

Reconstruct dielectrons at mid-rapidity

Coverage: $p > 0$ GeV/c

$|\eta| < 0.35$

$\Delta\phi = \pi$

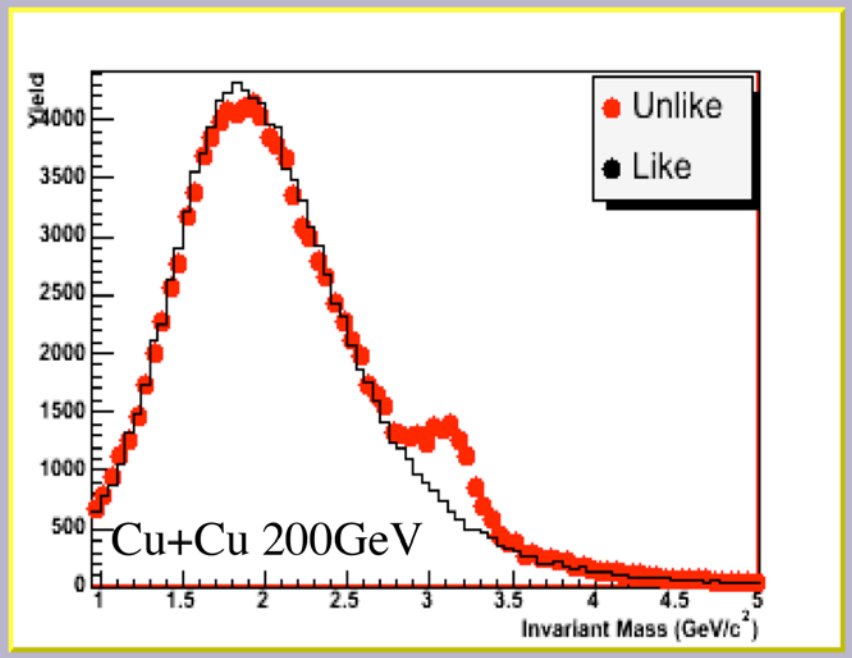


Lots of Cu+Cu Data!

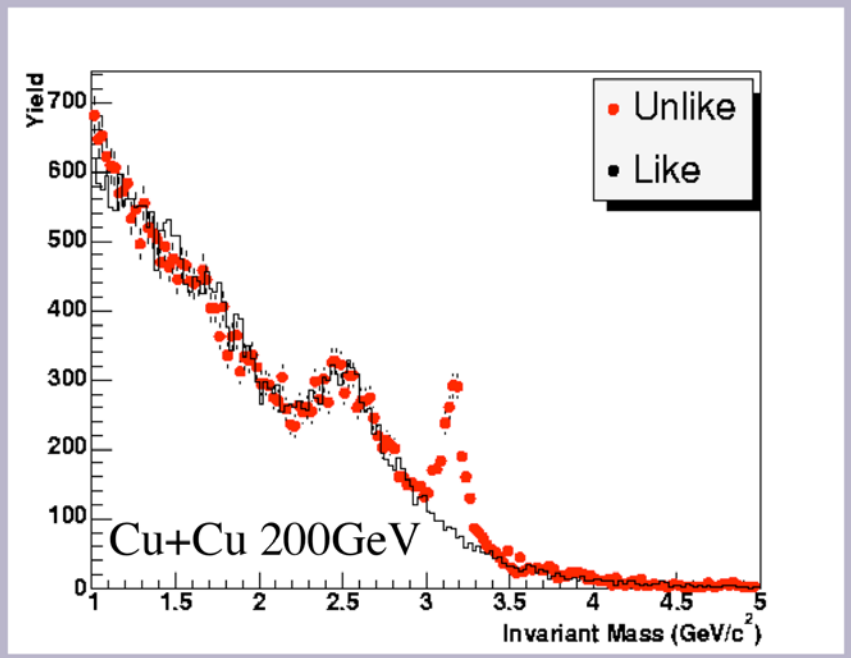
	62 GeV $J/\psi \rightarrow \mu^+\mu^-$	200 GeV $J/\psi \rightarrow \mu^+\mu^-$	200 GeV $J/\psi \rightarrow e^+e^-$
Int. Lum. Total	0.19 nb^{-1}	3.0 nb^{-1}	3.0 nb^{-1}
Int. Lum. Processed	0.15 nb^{-1}	2.6 nb^{-1}	2.6 nb^{-1}
nEvents	425×10^6	1.06×10^9	1.06×10^9
J/Psi Yield	146	10215	542

Invariant Mass Plots

$J/\psi \rightarrow \mu^+\mu^-$



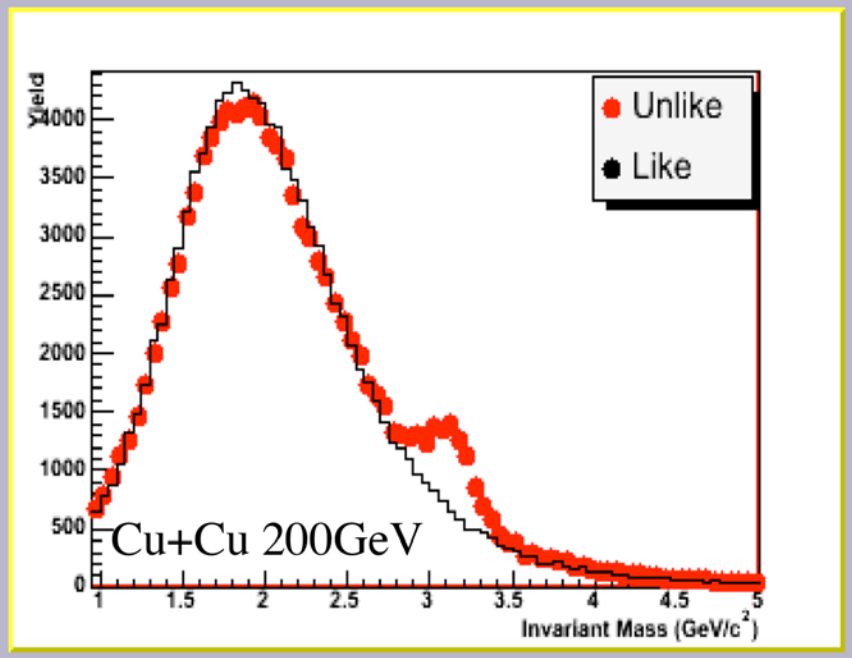
$J/\psi \rightarrow e^+e^-$



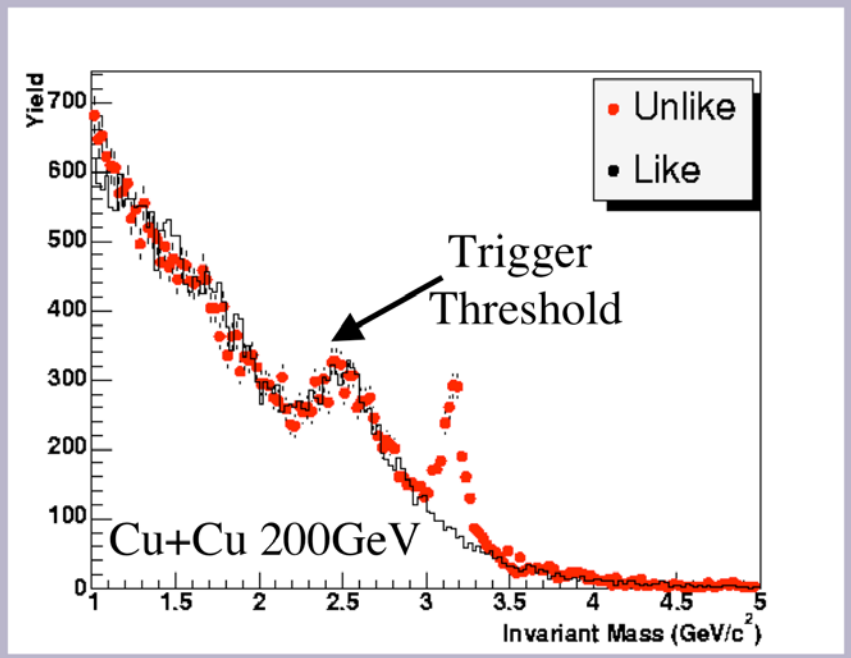
Raw J/ψ signal visible above the combinatorial and physical background of like sign dimuon and dielectron pairs

Invariant Mass Plots

$J/\psi \rightarrow \mu^+\mu^-$



$J/\psi \rightarrow e^+e^-$



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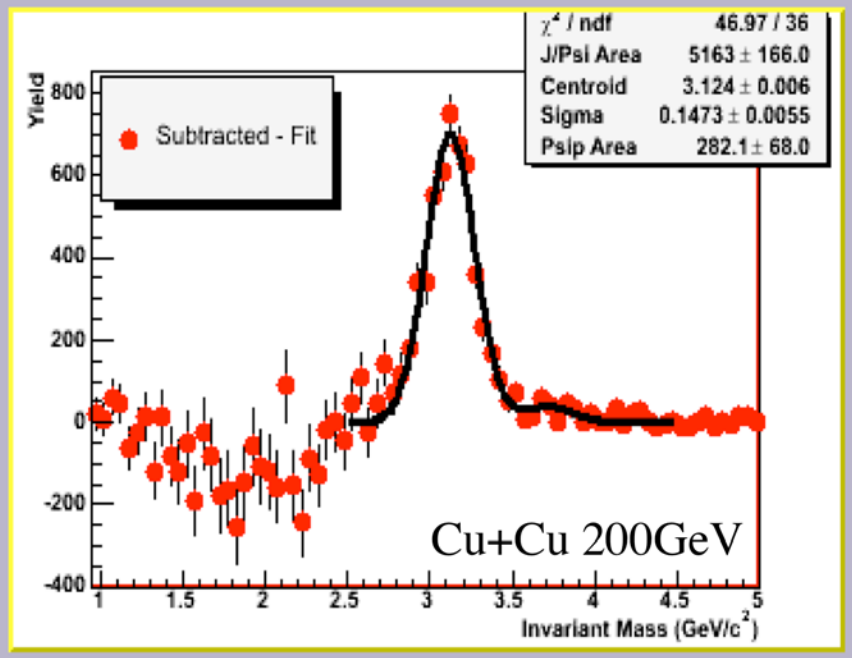

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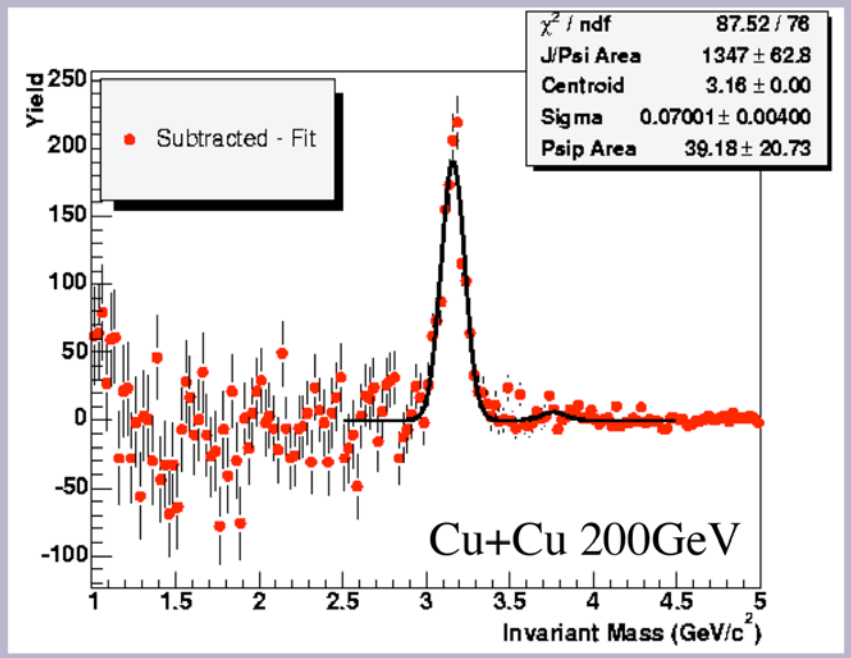
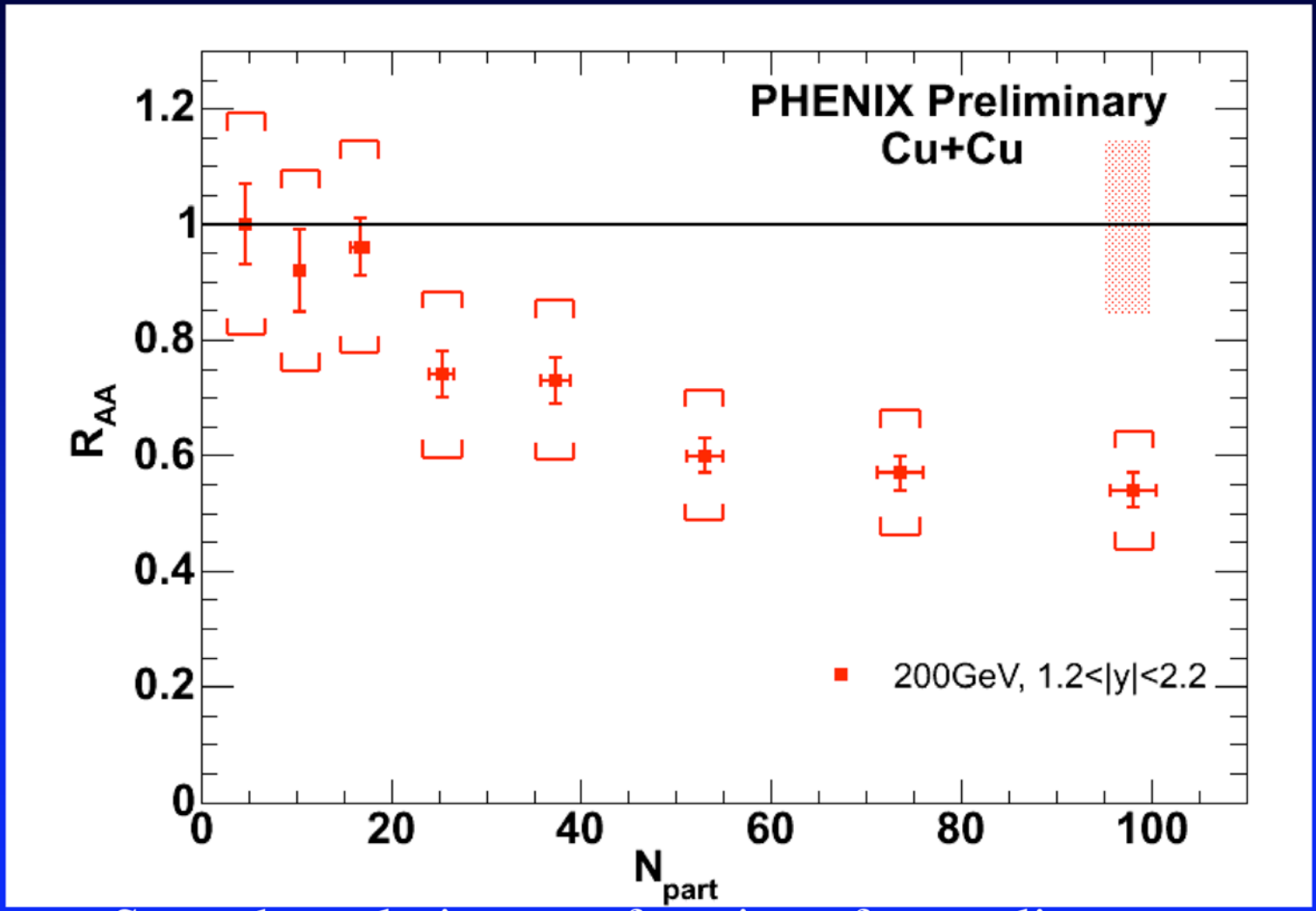


$$N_{J/\psi} = N^{+-} - 2\sqrt{(N^{++} * N^{--})}$$

Like sign subtraction method used to isolate J/ψ signal

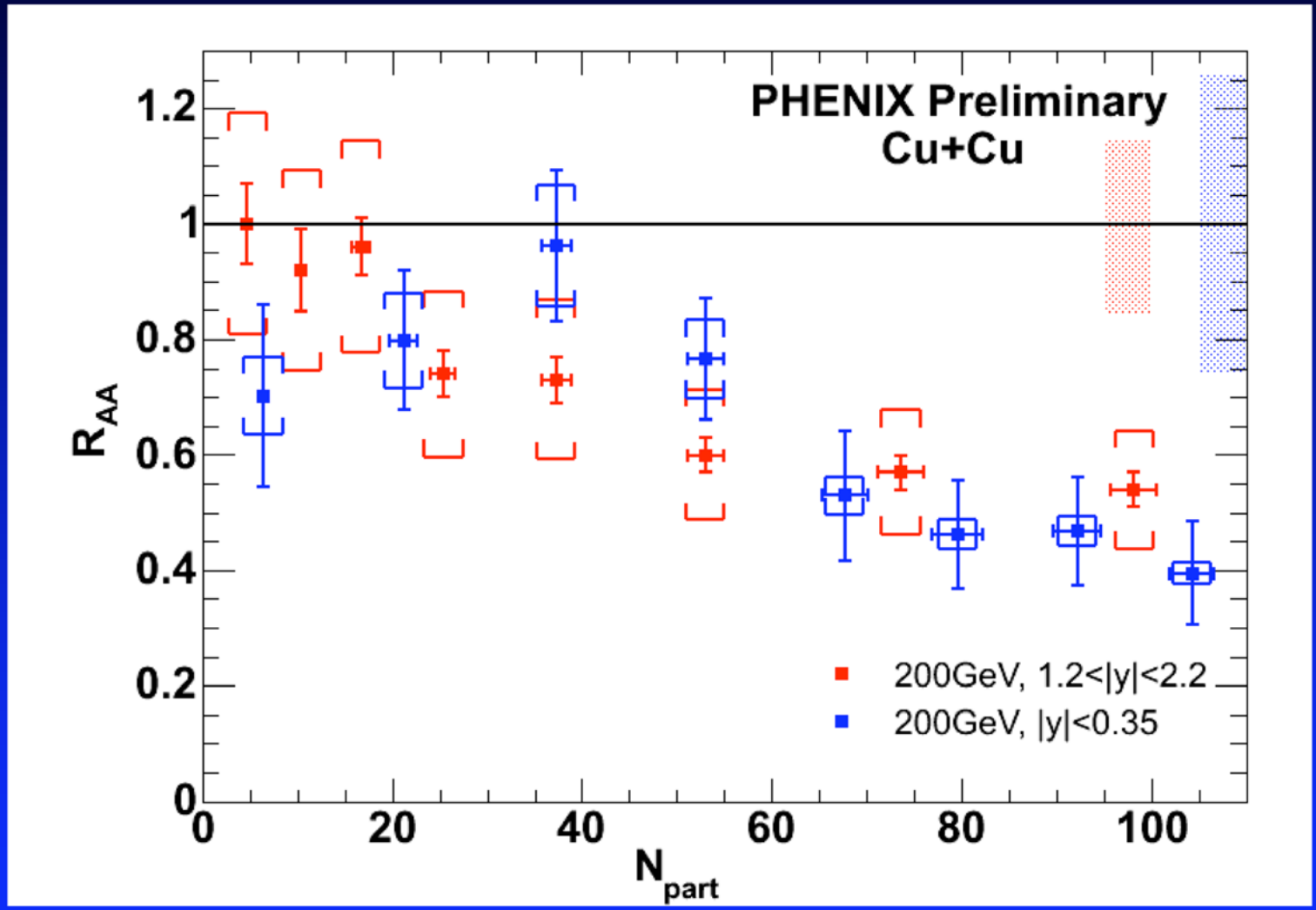
Integrate over mass range of 2.6-3.6 GeV/c^2

Nuclear Modification Factor



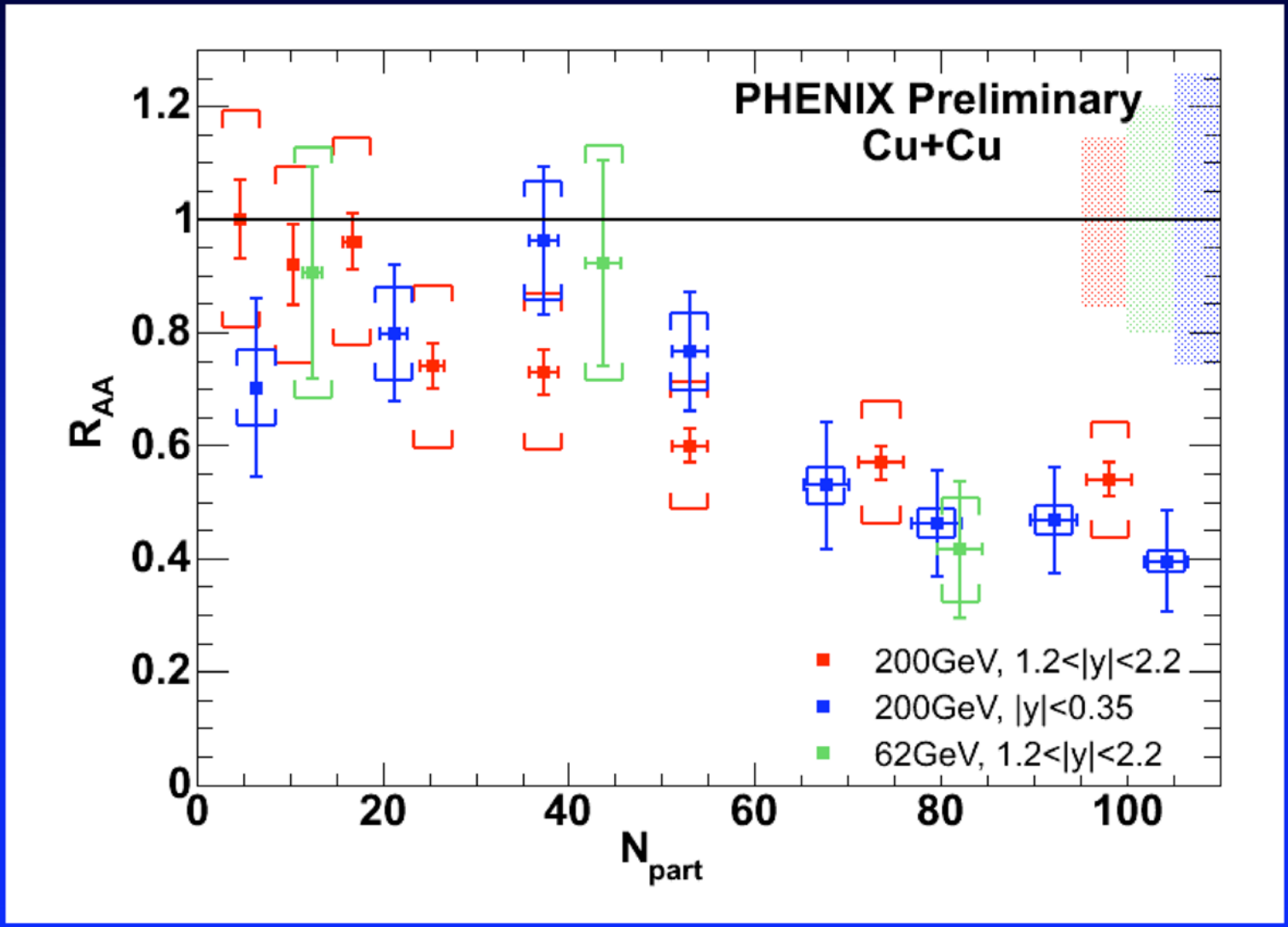
- Smooth evolution as a function of centrality
- Suppression factor of 2 observed in most central Cu+Cu 200 GeV collisions relative to p+p collisions

Nuclear Modification Factor



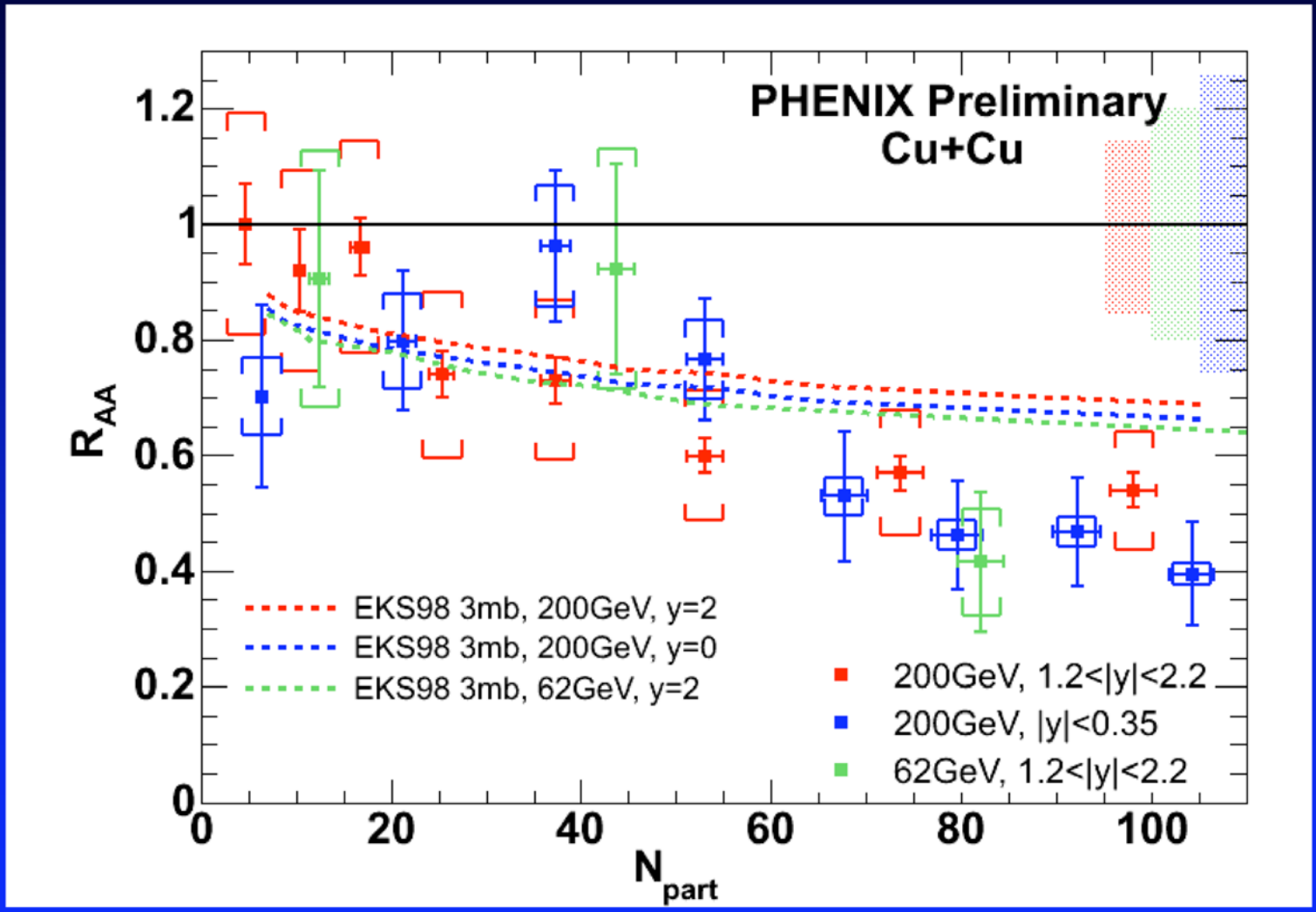
- Agreement observed between results obtained at mid-rapidity (y<0.35) and at forward rapidities (1.2<|y|<2.2)

Nuclear Modification Factor



- Same factor of 2 suppression between central and peripheral events observed in Cu+Cu 62GeV collisions at forward rapidity

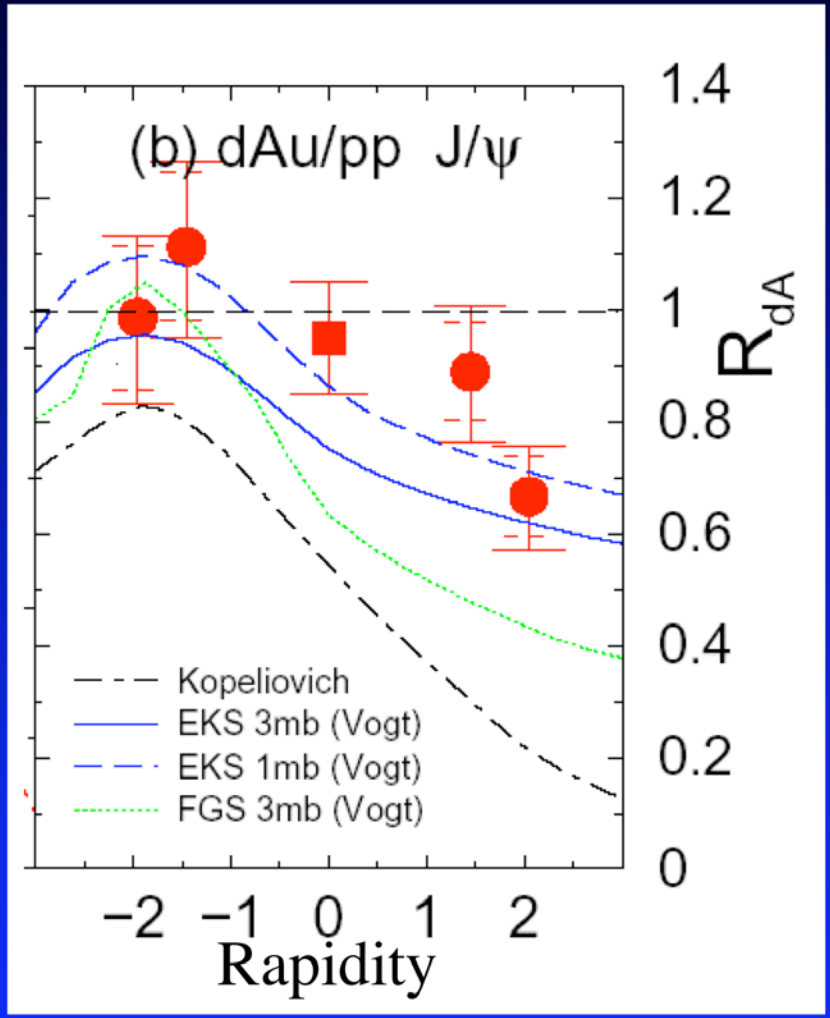
What do the theorists predict??



- Data consistent with cold nuclear matter calculations which expect little difference as a function of energy and rapidity
- Suppression observed in central events slightly larger than cold matter

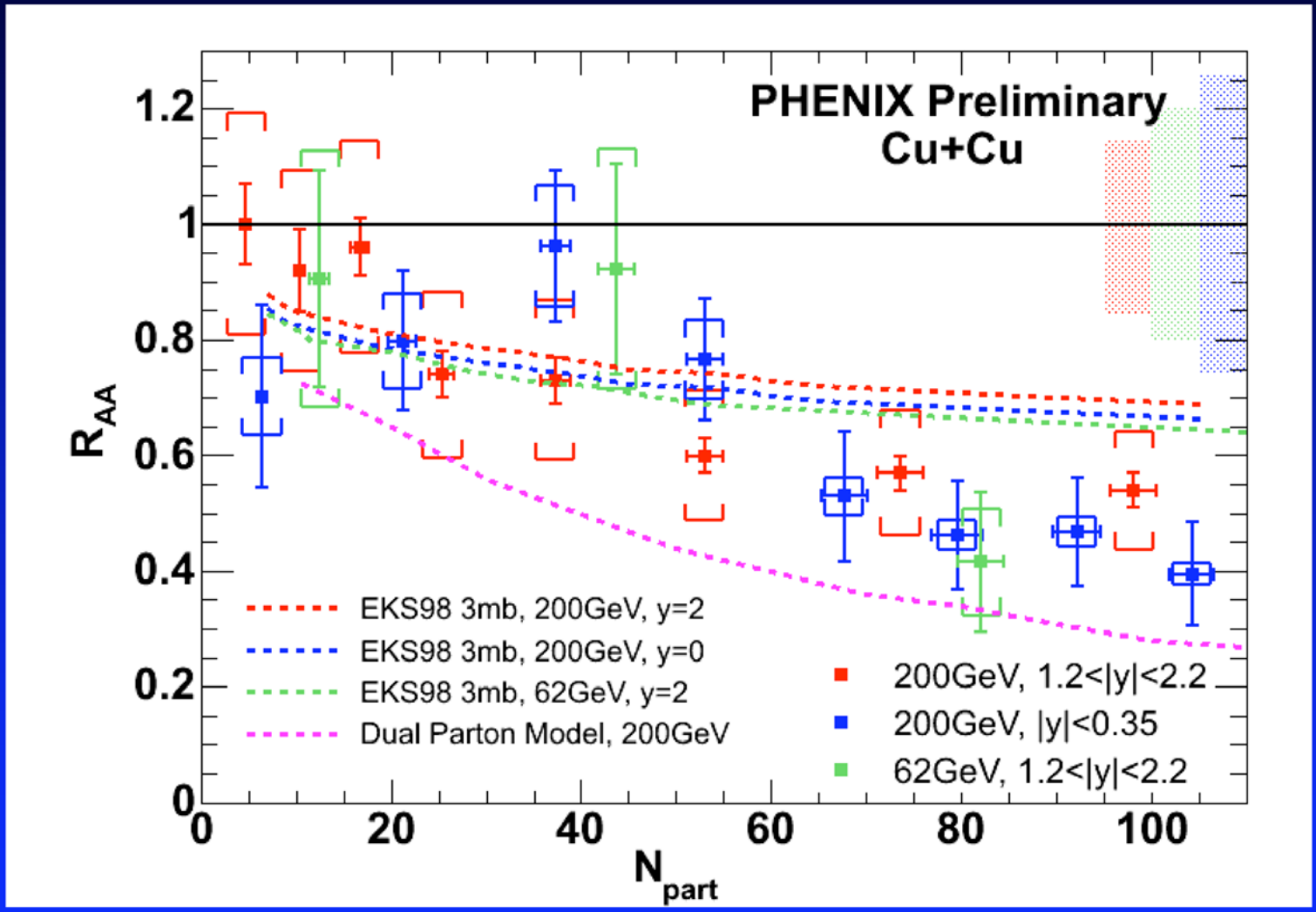
Theory Curves: R. Vogt nucl-th/0507027

Disclaimer: Cold Nuclear Matter



- J/ψ results from d+Au show best agreement with σ = 1mb
- Preferable to compare Cu+Cu results with predictions using this cross section instead of σ = 3mb

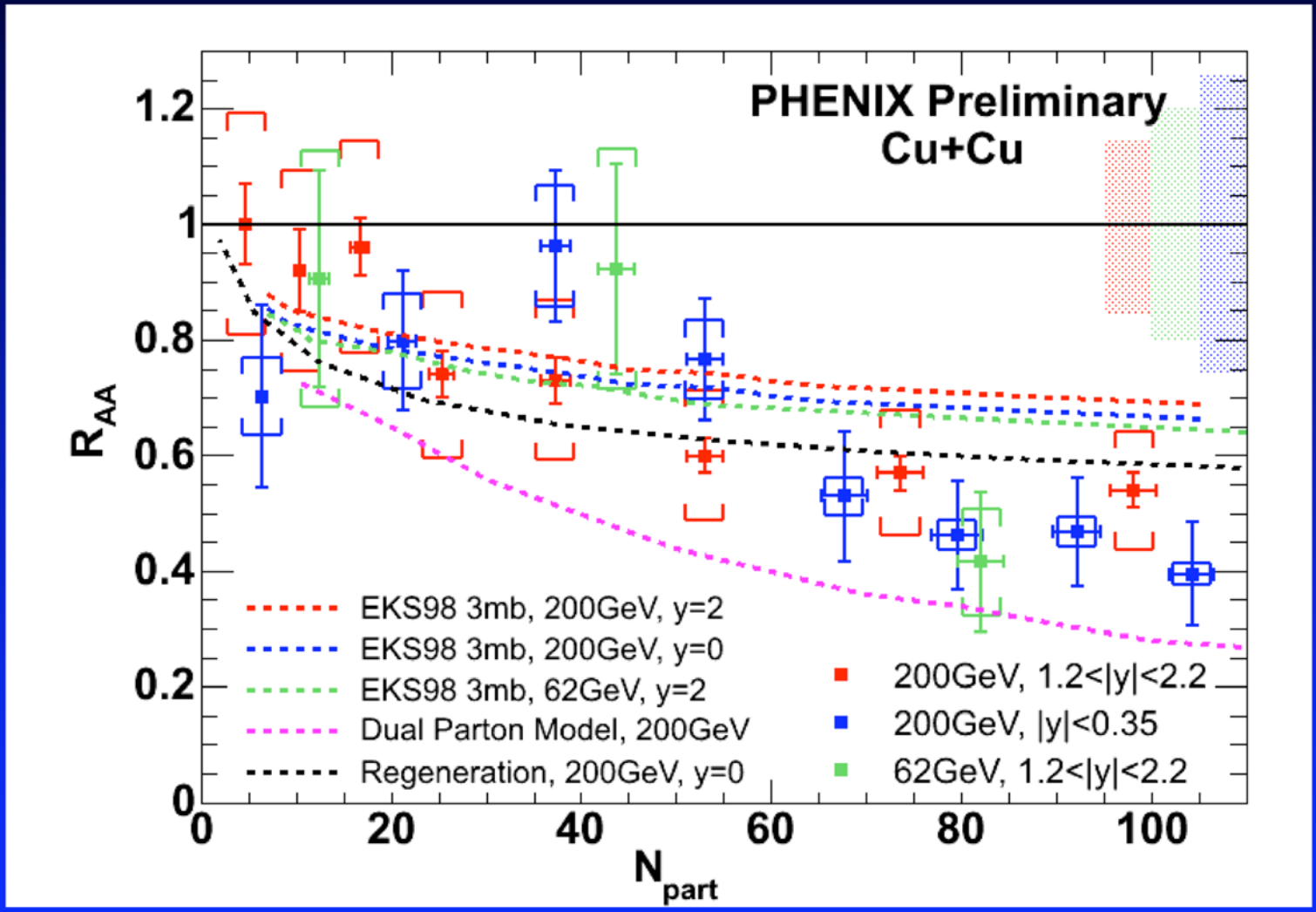
What do the theorists predict??



- Inclusion of final state screening effects enhances the degree of suppression
- Appears to over predict the suppression relative to what is observed in the data

Theory Curves: R. Vogt nucl-th/0507027, A. Capella hep-ph/0505032

What do the theorists predict??



- Inclusion of a regeneration mechanism reduces the suppression and is better able to reproduce the trend observed in the data

Theory Curves: R. Vogt nucl-th/0507027, A. Capella hep-ph/0505032, R. Rapp hep-ph/0502208

Recombination Rapidity Dependence

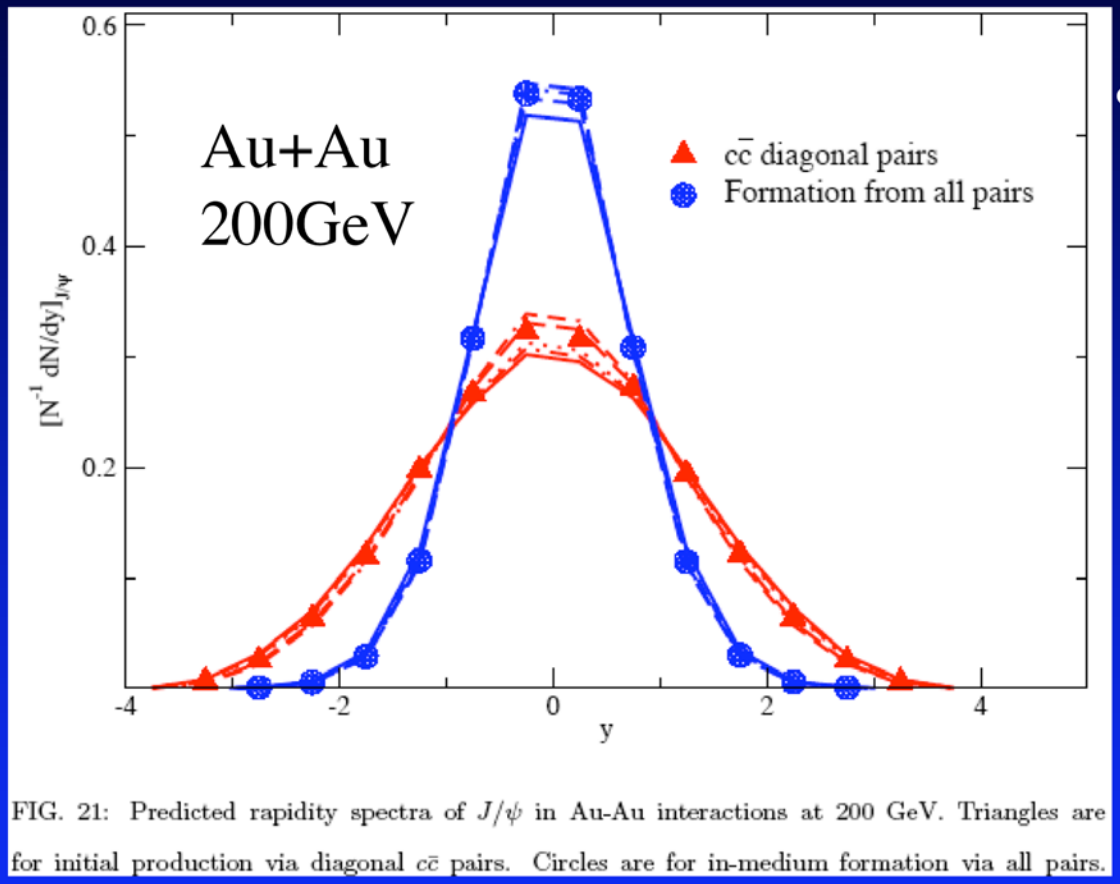
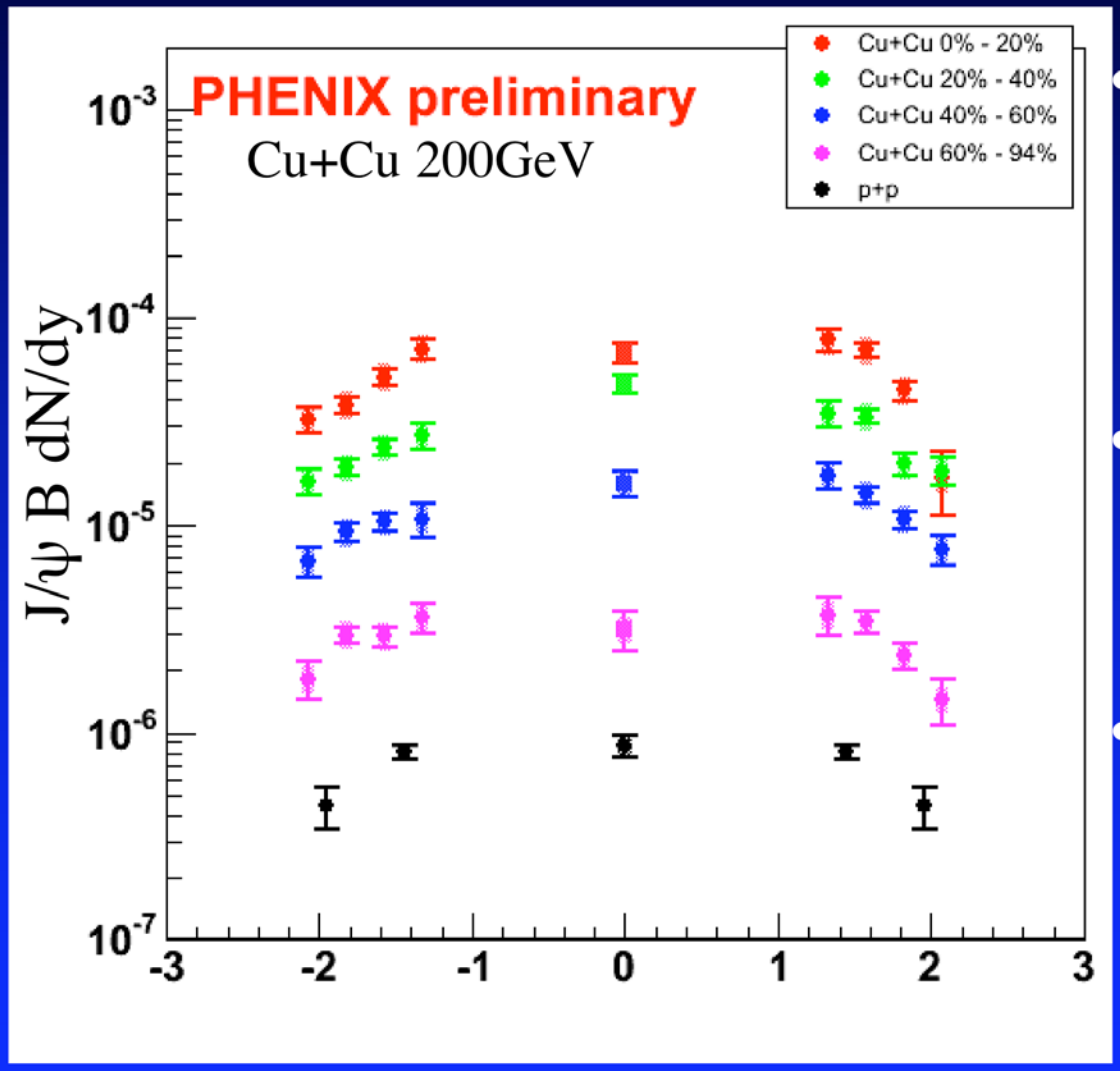


FIG. 21: Predicted rapidity spectra of J/ψ in Au-Au interactions at 200 GeV. Triangles are for initial production via diagonal $c\bar{c}$ pairs. Circles are for in-medium formation via all pairs.

* R.L. Thews nucl-th/0505055

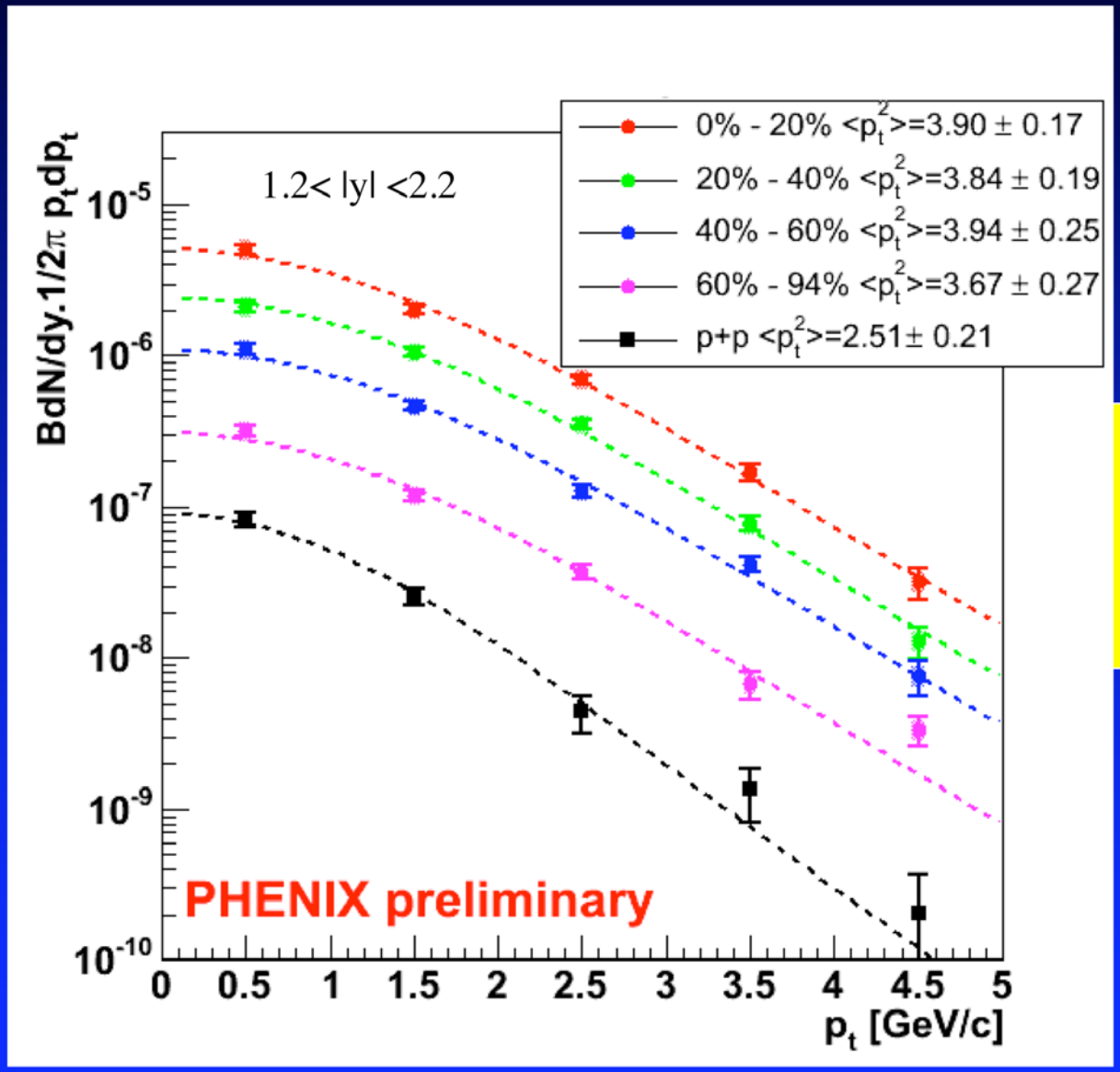
- Strong rapidity narrowing predicted by recombination models ⇒ Is this observed in the data?

Data Rapidity Dependence



- Strong rapidity narrowing predicted by recombination models⇒ Is this observed in the data?
- Shape of rapidity dependence of J/ψ yield consistent as a function of centrality
- No substantial difference observed between Cu+Cu and p+p distributions at 200GeV

Transverse Momentum Dependence

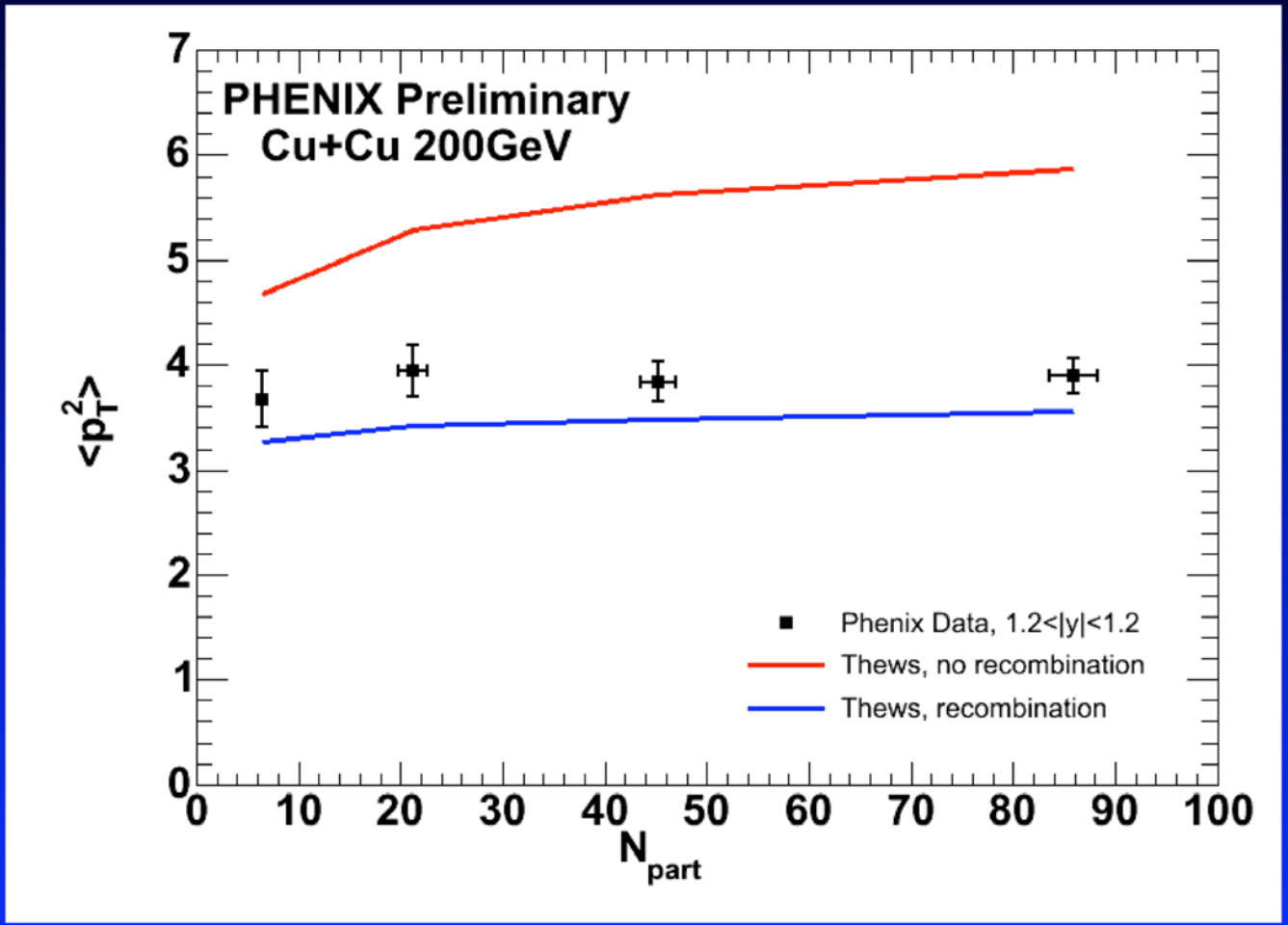


fit to extract $\langle p_t^2 \rangle$

$$f(p_T) = A[1 + (p_t / B)^2]^{-6}$$

$$\left\langle p_T^2 \right\rangle = \left(B^2 / 4 \right)$$

Transverse Momentum Dependence



- Data: $\langle p_T^2 \rangle$ is consistent with flat as a function of centrality
- Theory*: Red shows NLO calculation without recombination
  Blue shows effect of including J/ψ produced via recombination

* R.L. Thews, Quarkonium Formation from Heavy Quark Recombination", PHENIX Muon Workshop, June 13, 2005.

Summary

- J/ψ Suppression?
  1. Factor of 2 suppression in J/ψ R_{AA} in central Cu+Cu collisions at 200 GeV at both mid and forward rapidities
  2. Same suppression magnitude and trend observed in Cu+Cu collisions at 62 GeV, but statistical and systematic errors large

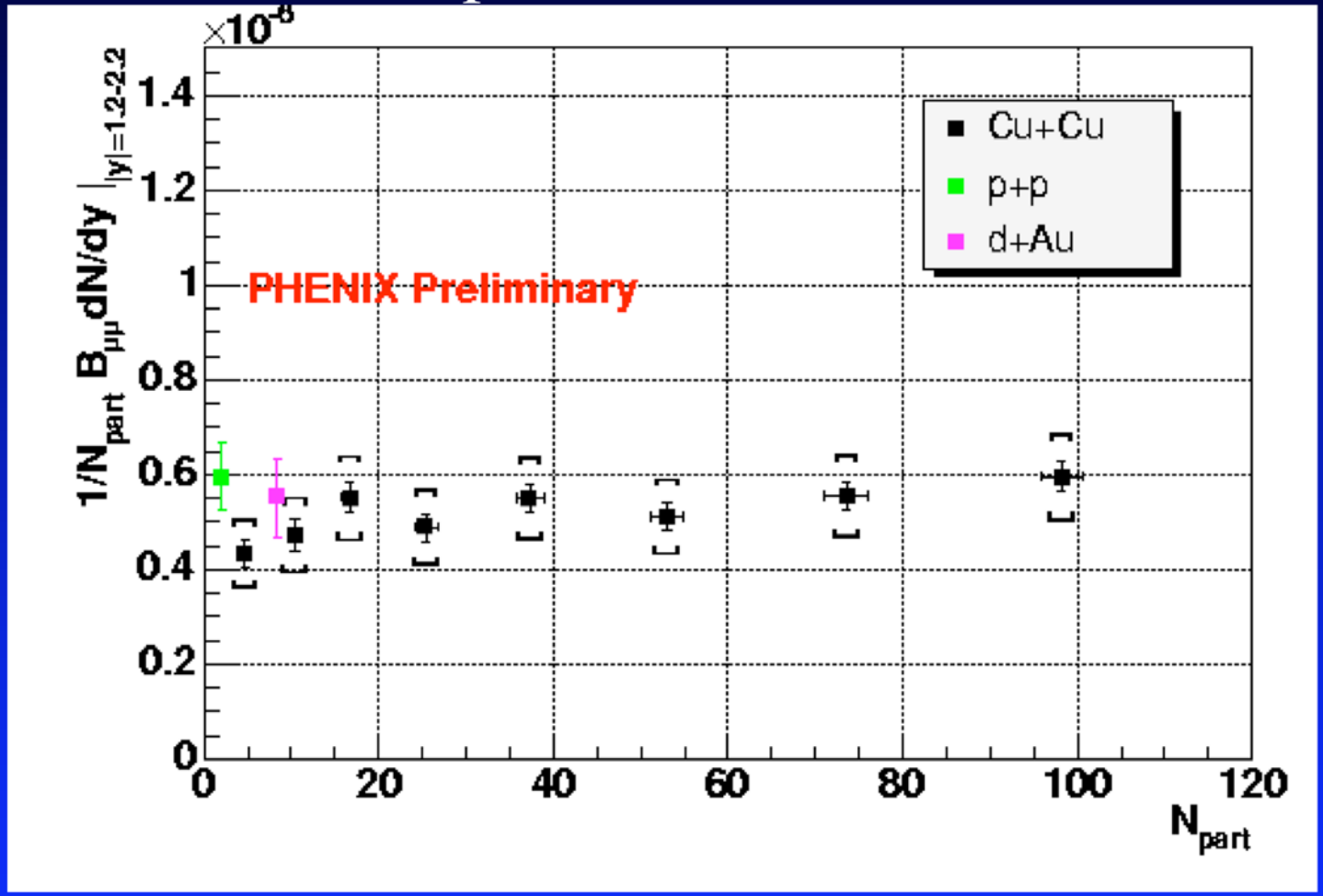
  ⇒ Does this imply the collision environment in both systems is similar? Not necessarily, but more could be learned if the large statistical and systematic errors in the 62GeV data were reduced
- J/ψ Recombination?
  1. Width of rapidity dependence of J/ψ yield does not change with centrality in 200 GeV Cu+Cu collisions
  2. Transverse momentum dependence of J/ψ yield shows no strong dependence on centrality in 200 GeV Cu+Cu collisions, but the overall magnitude is more closely reproduced by models containing recombination mechanisms than those without

  ⇒ Evidence mixed concerning whether recombination might contribute to the J/ψ yield in this collision system

Related Talks

- Ming Liu (EB.00005, Wed 10:15am): "Open Charm and J/Psi Production at Large Rapidities in dAu Collisions at RHIC"
- Taku Gunji (EB.00007, Wed 10:45am): "Measurements of J/Psi $\rightarrow$ e^+e^- in Au+Au collisions at sqrt{s_{NN}}=200 GeV by PHENIX at RHIC."
- MinJung Kweon (EB.00008, Wed 11:00am): "J/Psi production at forward rapidity in sqrt{s_{NN}}=200 GeV Au+Au collisions in the PHENIX experiment"
- A.Lebedev (EB.00009, Wed 11:15am): "Measurement of J/Psi Polarization via the Dielectron Decay Channel in sqrt{s_{NN}}=200 GeV d+Au and Au+Au Collisions by the PHENIX Experiment"

N_{part} Scaling



- J/ψ yield scaled by the number of participants is consistent with flat when plotted versus centrality